

## PHOTGRAMMETRIC DOCUMENTATION AND DIGITAL REPRESENTATION OF THE MACEDONIAN PALACE IN VERGINA-AEGEAE

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### ABSTRACT:

In this paper, the photogrammetric procedure and the development of a G.I.S. application for the digital documentation of the Macedonian Palace in the archaeological site of Vergina-Aegeae in northern Greece are described. Within this framework, the focus is targeted towards the use of UAV (unmanned aerial vehicle) for the production of high resolution orthoimages, essential for the interpretation, detection and measurement of archeological features. The advantages of model helicopters are seen in their ability to operate close to the object, to be flexible in navigation and in viewing directions. For the acquisition of the aerial images in the area of the 4<sup>th</sup> B.C. Palace in Vergina-Aegeae, a flight planning prior to fieldwork and a careful acquisition of the images was required to ensure successful postprocessing. The images were downloaded and processed already in the field in order to ensure good image quality, sufficient overlap between them and avoid large scale differences as well. The photogrammetric image processing of the data, comprising of the tie point measurement, bundle adjustment, DSM and orthophoto generation was done with the commercial software package LPS (Leica Photogrammetry Suite, Leica Geosystems), which offers functionalities for a complete photogrammetric working process. The resulting accuracy was acceptable for the 1:100 mapping. In addition to the above, within the general framework of the project, the development of a G.I.S. application with the commercial software package ArcGIS is described.

## 1. INTRODUCTION

### 1.1 Study area

The last 65 years the archaeological site of Vergina, in N. Greece (Fig. 1) has been an area of constant and systematic research of the Aristotle University of Thessaloniki (GR). The archaeological evidence proves that the site is associa-

ted with the ancient city lying on the north slopes of the Pierian mountains, securely identified as Aegeae, the old capital of the ancient Macedonian kingdom. The first excavations on the site were carried out in the 19th century by the French archaeologist L. Heuzey, who located the archaeological site and partly excavated the impressive palace and were resumed in the 1930's, after the liberation of Macedonia, by K. Rhomaios. After the Second World War, in the 1950's and 1960's, the excavations were directed by



Figure 1: Location of Vergina's archeological site in Greece

M. Andronicos, who investigated the cemetery of the tumuli. In the mid-seventies the Aristotle University under the directorship of Manolis Andronikos completed the excavation of the monumental royal residence, which covered an area of more than 10.000 square meters. (Fig. 2). Up to now, a large number of architectural remains, among which the Palace, the theater, the agora, and part of the impressive fortification of the ancient city are being revealed. The identification of the site with the old capital and royal necropolis of the ancient Macedonian kingdom sheds light to aspects of the history and cultural characteristics of the ancient Macedonians and their civilization. Among the monuments of the site, the Palace is one of the important monuments, which dates to the 4th century B.C. and is organized around a large, central peristyle court and comprises a circular shrine (Tholos) dedicated to Herakles Patroos (the mythical ancestor of the Temenid dynasty), and luxurious banquet halls for the king and his officers. From their mosaic floors one is still preserved in excellent quality.

Despite the long-lasting research and excavations, there has not been a complete and detailed documentation of its architectural remains. Such a detailed documentation is a prerequisite for any scientific work or assessment from national and international experts and a reference point for future research. Furthermore, recently the Hellenic Ministry of Culture decided to carry out restoration works in the area of the Palace and therefore the documentation is required prior to any other activity related to the preservation and presentation of the site.



**Figure 2:** Aerial view of the Macedonian Palace in the archaeological site of Vergina-Aegeae

## 1.2 Scope of the project

The documentation and mapping of the foundations of the Palace and its architectural remains with conventional methods is a time consuming process requiring allocation of large funds. Hence, the exploitation of photogrammetric techniques has the comparative advantage for the creation of a valid database, as support for a sound and reliable scientific publication.

From the technical point of view, the whole project is considered to be relative complex, due to the location of the site and the apparent difficulty in the interpretation,

measurement and 3D modeling of the archaeological remains (Fig. 3).



**Figure 3:** Panoramic view of the Macedonian Palace in the archaeological site of Vergina-Aegeae.

Different tools and a wide range of methodologies have to be applied and these consist of:

- a) surveying methods, using laser theodolite, for the acquisition of ground control points,
- b) an autonomous UAV (unmanned aerial vehicle) mounted with a digital camera, for the acquisition of large scale high resolution digital aerial images,
- c) digital photogrammetric techniques for the processing of the digital aerial images and the generation of value-added products (e.g. Digital Terrain Model, orthoimage),
- d) architectural methods for the creation of architectural designs and the representation of the remains,
- e) design and implementation of a GIS database, in which the raw data, i.e. the digital terrestrial and aerial images, GCPs, laser scanner data) and the photogrammetric products, i.e. orthomap, 3D representation of the whole site and the specific remains, architectural designs are included and further linked with other archaeological/ historical metadata. The database is an important tool for the storage, the management and the retrieval of metadata and spatial information related to the site.
- f) multimedia technologies, for the creation of a virtual tour of the site.

## 2. PHOTOGRAMMETRIC DOCUMENTATION

The photogrammetric documentation consists of the measurement of GCP's with traditional surveying methods, the acquisition of large scale aerial images with an autonomous UAV (unmanned aerial vehicle) and the photogrammetric processing towards the derivation of the DSM and Orthophoto products.

### 2.1 Measurement of GCP's

In the area of the Palace a number of 200 control and check points was established. Their coordinates were measured using a laser total station reflectorless TCR305 Leica, with an accuracy of 2cm in planimetry and height. These points were mostly corners of archaeological remains, centers of the circular surfaces at the top of steel columns in the central part of the curt and 70 tennis balls stuck with nail in the ground, being traceable in all the images. (Fig 4). Figure 5 shows the distribution of the control and check points in the area.



Figure 4: Different types of control points.

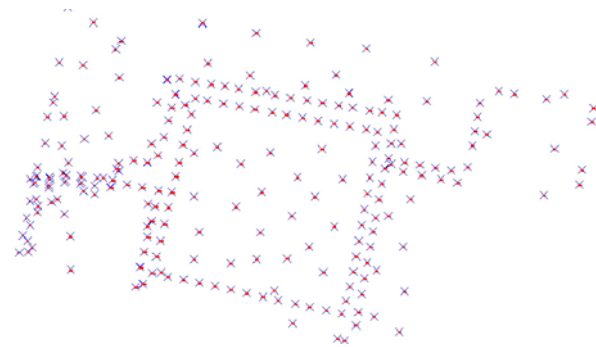


Figure 5: Distribution of control and check points

## 2.2 Image acquisition

The new concept of UAV-based data acquisition is of particular interest for archaeological and cultural heritage applications, while the last years the applications of UAV-systems in photogrammetry are constantly increasing. This development can be explained by their capability to fly nearby the object from different positions and to combine aerial and terrestrial acquisitions (Wester-Ebbinghaus, 1980), plus they can be navigated with relative high accuracy (<1 dm) to the predicted acquisition points even with low cost GPS/INS systems. UAVs are considered ideal for a low cost image acquisition of small areas or sites without the requirement of special permissions to conduct the flight.

For the photogrammetric recording of the area of the Palace, we used a UAV-helicopter equipped with the 8 MPixel (3456 x 2304) digital camera CANON EOS 350D (Fig. 6). The camera was mounted on a special platform to eliminate the vibrations of the helicopter, able to rotate 360 degrees in horizontal and vertical direction. For ensuring sufficient image overlap, the signal from a video camera, installed on the helicopter, was transmitted to the ground control station via RF and displayed on a monitor. The activation of the shutter for acquiring the image was controlled from the ground unit. Due to time restrictions in the acquisition of the data, e.g. opening hours of the archaeological site, and the requirement to acquire the images before the end of January (closing date of the site for a 2 year period for restoration works), we had to complete the flight as fast as possible during the daytime, in order to ensure good radiometry in all the images of the block.



Figure 6: The camera mounting on the helicopter.

In order to produce the final orthophoto with a scale of 1:100, the helicopter acquired images from an average flying height of 30 m (Fig. 7), corresponding to an average image scale of 1:1'666. The ground coverage in each image frame, considering the above average image scale and the sensor size was 37 x 24.7 m. Nine strips of images were acquired with approximately 60 % and 30 % overlap along and across the strips (Fig. 8). However, due to perturbations of the helicopter, occurring from sudden winds, it was difficult to always control the vehicle pose and take images over the predicted acquisition areas. The images were downloaded and processed already in the field in order to ensure good image quality (e.g. no blurring due to movement of the UAV, no saturation due overexposure, no sun reflections), sufficient overlap between the images (60% – 80% and 20%-30%, along and across strips respectively). The largest and smallest image scale from all used images (Table 1) was 1:1'000 and 1:2'500. Even with the smallest scale of 1:2'500 the corresponding GSD of 1.6 cm was acceptable for the 1:100 mapping.



Figure 7: The helicopter during the acquisition of the aerial images in the archaeological site of Vergina

No. Strip	1	2	3	4	5	6	7	8	9
No. acquired images	44	40	39	93	33	33	30	25	22
No. used images	10	8	10	13	14	12	10	5	5

Table 1. Number of images in each strip

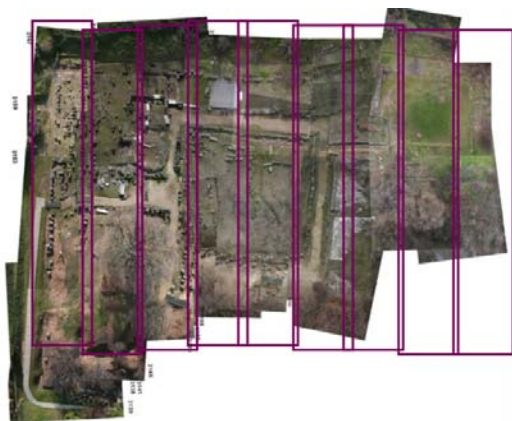


Figure 8: Flight planning.

### 2.3 Photogrammetric processing

The photogrammetric image processing of the data, comprising of tie point measurement, bundle adjustment, DSM and orthophoto generation, was done with the commercial software package LPS (Leica Photogrammetry Suite, Leica Geosystems) (Fig. 9), which offers functionalities for a complete photogrammetric working process.

As a first step, the process of Block Triangulation concerned one strip at a time. After that, all the strips were solved as a block. The GCPs were assigned a standard deviation of 2cm. It is noted that from the total amount of measured GCPs, only the 70 tennis balls were used in the procedure as control or check points. Mainly because the identification of the non-signalized points that were measured on the surface of the archaeological remains (marbles or stones without clear shape and edges) was very difficult. The procedure of point measurement was carried out in monoscopic way. The lens distortion model with 2 parameters was used as additional parameter function. The computed RMS errors for the check points was 2.5 cm in planimetry and 4.0 cm in height.

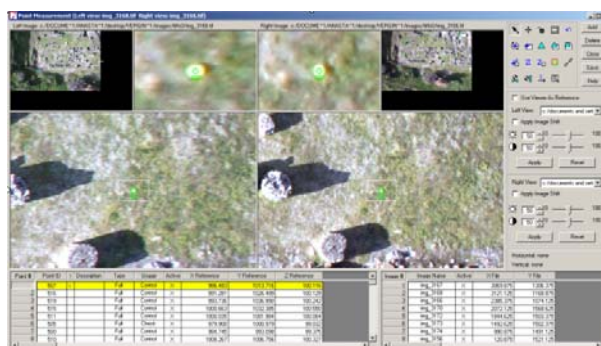


Figure 9: Photogrammetric image processing using LPS (Leica Photogrammetry Suite, Leica Geosystems)

Because of the large number of photographs and the varied type of soil surfaces in the archaeological area –due to the spread architectural remains of the Palace-, DTMs were produced from each individual strip and merged together in a final stage (Fig. 10). For each strip the adopted DTM strategy varied. The cell width values ranged between 0.5 and 1m. The mass point quality was about 70-80% for all

the strips. For the check points, the computed RMS error was 15cm.

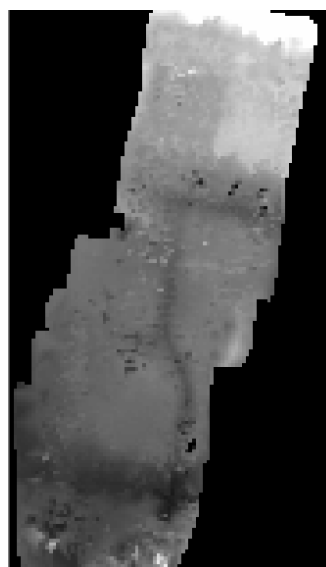


Figure 10: DSM production using LPS

Following the DTM extraction, the orthophoto generation process was carried out. For the resampling process a pixel size of 1cm was selected. The generation of the final orthomosaic (Fig. 11) was the most time consuming procedure.



Figure 11: The orthomosaic of the area of Macedonian Palace in the archaeological site of Vergina-Aegeae.

### 3. G.I.S APPLICATION

The development of a G.I.S. application with the commercial software package ArcGIS followed the production of the orthomosaic of the Macedonian Palace. Meanwhile, the photographic documentation (Fig. 12) of the architectural remains and archaeological findings took place, a registration form has been edited for all items. A unique code was given for each archaeological finding. Features such as type, rhythm, dimensions, materials, technical characteristics, marks of elaboration or repair, condition of maintenance and conservation, were filled in this registration form. Afterwards a database was created according to the registration form. The G.I.S. application allowed the final linkage of the Database and the orthomosaic, the digital cartographic background.



**Figure 12:** Photographic documentation of the archaeological findings and architectural remains

#### 4. FUTURE WORK AND CONCLUSIONS

In this phase of the project we have proceed with the photographic documentation, in order to integrate this information into the GIS Database. A further step will be the geometric documentation of the architectural elements – parts of the Palace. Three different methods will be applied in order to measure the geometric characteristics of the elements. These are: photogrammetric documentation, use of terrestrial laser scanning and architectural drawing. This work will be towards a better interpretation and correlation of the architectural elements with the archaeological hypothesis in order to produce a virtual photorealistic 3D model of the Palace. The 3D model will be used for different purposes: a) in a multimedia application for the presentation of the site b) as a basis for further archaeological analysis, scientific work or assessment from national and international experts and a reference point for future research and c) the future restoration of the Palace.

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